NOTES

The science of greenhouse gas reduction targets:
What is needed to avoid dangerous climate change?
The "zero-minus fast, with cooling" target

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The position on greenhouse gas reduction targets that is being presented here is adopted policy of the Greenleap Strategic Institute, Beyond Zero Emissions and the Western Region Environment Centre.

A very similar position, that of zero emissions, has been adopted by the 12 member groups of the Zero Emissions Network.

The Central Victorian Greenhouse Alliance and the City of Melbourne have since 2001 and 2002 respectively, adopted a policy of net zero emissions by 2020.

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A distinctive underlying philosophy has driven the development of the "zero-minus fast" target.

The first assumption is that we need to be "doubly-practical" – that is we need to be committed to getting things done in the real world (and not just endlessly talking) but that what we get done is really going to solve the problems we are concerned about. You can hardly say it's practical to take action in a way that will not solve the problem.

So this means we need to be committed to actually achieving sustainability, and not only achieving it but doing so really fast so that the losses of things we value (ie. the things/attributes that are not sustained) are kept to the absolutely lowest possible level.

Also part of the underlying philosophy is the notion of backcasting. When there is urgency and also substantial barriers in the way of large-scale change it is essential to have a very clear idea of what change is needed, its scale and necessary timeframe. Only if all this is known is it possible to apply our creativity to reaching the goal in a timely way. The alternative approach of incrementally edging away from an undesirable situation or toward a *poorly understood* preferred situation is likely to be a slow process, prone to blockages and false starts/dead ends. If a pure non-backcasting approach is used then any success has to be purely accidental!

The Natural Step program has developed a special variant of backcasting based on the achievement of principles. The principles guide the development of change processes that cause an idea future to grow as an emergent property. The Lean Thinking movement that is having a big impact on boosting business productivity use a related approach of backcasting from an ideal future that emerges from the application of lean thinking principles.

Natural Step: http://64.207.158.76/au.naturalstep.org/index.html
Lean Thinking: http://www.leanuk.org

Book: excellent whole-system thinking method guide built around backcasting
http://www.leanuk.org/pages/Lean_books_seeing_the_whole.htm

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Building targets on a foundation commitment to actually achieve sustainability is easier said than done. Many people are not sure what sustainability means in practice.

In developing the "zero-minus fast" target we have used a definition of sustainability that cuts through the confusion.

It is assumed that 'sustainability' means the ability to sustain, and that 'sustain' means to maintain or keep going. In order to really understand what a person is taking about when they talk about things to do with sustainability you need to clarify what is to be sustained.

For the purpose of establishing an appropriate target for greenhouse gas reductions and the prevention of harmful climate change, it is assumed that we should try to sustain: (a) all people globally and all species (b) life support systems and ecosystem and geosystem services. The motivation for (a) is ethical (people and other species are what we care for empathetically. The motivation for sustaining (b) is practical because people and other species depend for survival and quality of life on the these systems and their ‘services’.

http://www.ces.vic.gov.au/
http://tinyurl.com/dll5v -link to 40p PDF file “A perspective on environmental sustainability” Philip Sutton

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This section looks at the impacts of climate change.

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This slide shows that the trend in global temperature has been solidly in the direction of warming in the period of intense industrialisation.

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Already drought conditions in many parts of the world are serious. Some areas are wetter but most are drier. Higher temperatures lead to higher evaporation so in most cases even if the rainfall increases due to global warming, the retained water in the soil is less than before.

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The data since 1950 shows big increases in the number of floods in most parts of the world. A hotter world leads to more evaporation and to more severe weather events – hence more floods in most places.

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The insurance industry has experienced a very big increase in insurance losses due to “natural” catastrophes – largely due to extreme weather events. This explains why sections of the insurance industry has been very active in raising awareness of the climate issue.

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Climate change induced changes are beginning to impact people in many parts of the world – especially the poorer areas that have less adaptive capacity.

As understanding of climate science grows it is becoming clearer how climate change impacts on people often through interactions with other issues. For example it was once believed that desertification in sub-Saharan Africa was due largely and directly to tree clearance. Now it appears that global warming induced changes in the path of rainfall bearing winds over North Africa have set of a drying. The clearing of trees (which makes the drying pattern worse) may well have been encouraged by the drying conditions. Furthermore much of the social turmoil and violent conflict in the region may have been catalysed by the drying conditions.

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It is now clear that climate change is already reducing environment-dependent economic activity and stressing social systems and that this in turn is adding to the level of global insecurity. The situation is only going to get worse as global warming intensifies.

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Donald Rumsfeld (recently retired) once told a press conference that knowledge fell into three categories: (a) ‘known knows, (b) ‘known unknowns’, and (c) ‘unknown unknows’, meaning: (a) topics/possibilities we know a lot about, (b) *identified* topics/possibilities we know little about, and (c) topics/possibilities that we haven’t even identified (ie. complete surprises).

The material immediately following deals with (a) and (b).

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Climate scientists, especially in the European Union, have argued that we must not exceed 2ºC warming over the pre-industrial level because above 2ºC changes are expected to occur that will have catastrophic effects on species loss, desertification and sea level rise.

However, for obvious reasons species dependent on icy and snowy environments (the cryosphere) are under intense pressure already as these environments contract and in some places disappear altogether.

It is interesting to see that when groups with an interest in nature conservation look directly at the impact of climate change on their core area of concern, they can see that many species and ecosystems are already under very serious stress.

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In Feb 2005, close to the time that the Kyoto Protocol came into force, a conference was held Exeter, UK, to advance scientific understanding of and encourage an international scientific debate on the long term implications of climate change, the relevance of stabilisation goals, and options to reach such goals; and to encourage research on these issues. http://www.stabilisation2005.com

The proceedings of this conference were produced as a book, *Avoiding Dangerous Climate Change,* in January 2006. The book is downloadable from: http://www.defra.gov.uk/environment/climatechange/internat/dangerous-cc.htm

One of the papers at the conference/chapters of the book looked at species responses to climate change and the need to set a significantly lower warming limit. Actual experience with species responses to climate change so far has shown that species are more sensitive to warming than was expected when the 2ºC warming over pre-industrial levels was adopted. The authors, van Vliet and Leemans, recommended that the cap be tightened to 1.5ºC.

Impacts already being experienced arise from many causes. Some important ones are: * rising temperature leading to the shrinkage of the cryosphere and collapse of ecosystems dependent on heat sensitive species eg. coral reefs, * desertification, * rapid movement of climatic zones (poleward and into higher elevations) that is faster than species can migrate (isotherms, lines of given temperature, are now moving poleward at 50 km per decade), and * increasingly severe weather events.

(Source for isotherm movement: J. Hansen, NASA Goddard Institute for Space Studies)

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James Hansen , head of the climate change program at the NASA Goddard Institute for Space Studies, and quite a few other scientists are very concerned that the current level of warming is enough or very close to enough to result in the 'irreversible' loss of the Greenland ice sheet. This in turn could destabilise the West Antarctic Ice Sheet (see below).

http://en.wikipedia.org/wiki/West_Antarctic_Ice_Sheet

Potential collapse of the West Antarctic Ice Sheet

In January 2006, in a UK government-commissioned report, the head of the British Antarctic Survey, Chris Rapley, warned that this huge west Antarctic ice sheet may be starting to disintegrate, an event that could raise sea levels by at least 16 feet. [Estimates by others have ranged from 20 to 50 feet.] Rapley said a previous Intergovernmental Panel on Climate Change report playing down worries about the ice sheet's stability should be revised. "The last IPCC report characterized Antarctica as a slumbering giant in terms of climate change," he wrote. "I would say it is now an awakened giant. There is real concern." [3]

Rapley said, "Parts of the Antarctic ice sheet that rest on bedrock below sea level have begun to discharge ice fast enough to make a significant contribution to sea level rise. Understanding the reason for this change is urgent in order to be able to predict how much ice may ultimately be discharged and over what timescale. Current computer models do not include the effect of liquid water on ice sheet sliding and flow, and so provide only conservative estimates of future behaviour." [4]

Jim Hansen, a senior NASA scientist who is a leading climate adviser to the US government, said the results were deeply worrying. "Once a sheet starts to disintegrate, it can reach a tipping point beyond which break-up is explosively rapid," he said. [5]
Indications that climate change may be affecting the west Antarctic ice sheet comes from three glaciers, including Pine Island and Thwaites. Data reveal they are losing more ice - mainly through the calving of icebergs - than is being replaced by snowfall. According to a preliminary analysis, the difference between the mass lost and mass replaced is about 60%. The melting of these three glaciers alone is contributing an estimated one-hundredth of an inch per year to the rise in the worldwide sea level.[3]

Impact of Greenland ice sheet melting

While models predict significant melting of the Greenland ice sheet as summer temperatures in the Arctic rise by 3C degrees to 5C (5.4F-9F), most models suggest that the ice sheets of Antarctica will remain more stable. However, historical data shows that the last time that Greenland became this warm, the sea level rise generated by meltwater destabilised the Antarctic ice. That means that the models of sea-level rise used to predict an increase of up to 3 feet by 2100 may have significantly underestimated its ultimate extent, which could be as great as 20 feet. [6]
This conclusion emerged from a study that used data from ancient coral reefs, ice cores and other natural records to reconstruct the climate during the last gap between Ice Ages, between 129,000 and 116,000 years ago. Scientists used computer models to show that meltwater from Greenland raised the sea level by up to 11ft, but coral records showed that the total global rise was between 13ft and 20ft. The most likely explanation is the melting of Antarctic ice sheets: as sea levels rose, the floating ice shelves off the coast of the continent would have become more likely to break up. That in turn would have allowed glaciers to dump more ice from the continent itself into the sea. The base of the West Antarctic ice sheet currently lies below sea level, which allows ice to escape to the sea easily.[6]
(Go to web link for references.)

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Species losses:

Climate change alone is expected to force a further 15%- 37% of species to the brink of extinction within the next 50 years.
http://www.guardian.co.uk/conservation/story/0,,1824726,00.html

Ocean acidification:

http://en.wikipedia.org/wiki/Ocean_acidification

http://www.wbgu.de/wbgu_sn2006_kurz_engl.pdf
The pH of ocean surface waters should not drop more than 0.2 units below the pre-industrial level in any larger ocean region (i.e. also in the global mean).

Ken Caldeira, Carnegie Institution, Stanford (pers. comm.): The whole of the world's oceans will exceed the 0.2 pH units limit with 550 ppm CO2 (pure, not CO2e). It it likely that none of the world's oceans will exceed the limit at 450 ppm CO2 (pure, not CO2e). Ken Caldeira believes that the 02 pH unit decrease limit might be too lenient.

Recovery from ocean acidification (through natural neutralisation) is extremely slow – about 5-10 thousands of years.

Loss of the Amazon:
http://en.wikipedia.org/wiki/Amazon_Rainforest

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Perhaps a majority of climate scientist are concerned that it might be possible for global warming to trigger a runaway phase.
http://archive.greenpeace.org/climate/database/records/zgpz0638.html
Other references:
http://www.tyndall.ac.uk/research/theme1/project_overviews/t3_18.shtml

Some further comments on the drivers:
Loss of ice reflectivity: Ice reflects about 90% of incident sunlight back into space. As sea ice and terrestrial icefields dwindle in extent it is replaced by much more absorbent oceans and forests.
Reduced capacity to absorb CO2 – terrestrial vegetation and marine ecosystems. The biggest 'sink' for CO2 is the ocean and the largest mechanism for its absorption is uptake by photosynthetic plankton. When sea temperatures rise the surface waters become nutrient poor limiting the growth of plankton and thus the absorption of CO2. In terrestrial environments higher temperatures result in many areas becoming drier and more frequently subject to fire. The desiccation limits the growth of plants and their ability to capture CO2 is reduced.
Loss of bushland due to fire/drought. Drought and fire result in the death and rapid oxidation of plant material resulting in the conversion of existing bio-sequestered CO2 being liberated into the atmosphere.
Increased mobilisation of organic carbon – permafrost, soils, peat. Rising temperatures melts the permafrost allowing stored methane to be released as either methane (in wet conditions) or as CO2 (in dry conditions) , warming of soils favours the metabolism of soil organic carbon and its release as CO2, and rising CO2 levels lead to higher acidity of the water flowing through peat with the result that peat is gradually dissolved and passes into streams where it is metabolised to CO2.
Expansion of dark heat-absorbing forests in Northern Hemisphere high latitudes. In the higher latitudes in the northern hemisphere permafrost environments give way to expansion of pines with darker (heat absorbing) foliage. As a consequence the albedo of the earth is reduced and more heat is retained.
Lack of new regions for intense plant growth: in previous warmings the world was wilderness and so as things heated up new regions became available for intense plant growth eg. fern forests in the Arctic Circle (with consequent substantial sequestration of carbon). Pressure for food production and living space may now prevent this.
Decreased cloudiness: With very strong initial warming cloudiness can decline enabling positive feedbacks to overwhelm negative feedback effects. Big reductions in oceanic plankton might contribute to the lowering of cloudiness despite there being more H2O in the air at higher temperatures, since plankton produce materials that contribute to cloud seeding.
http://adsabs.harvard.edu/abs/2005ClDy...24..685B
Mobilisation of methane hydrates (associated with two major extinction events: the Permian-Triassic (P-T or PT) extinction event 251 million years ago and the

Paleocene-Eocene Thermal Maximum (PETM) 55 million years ago) can occur when sea temperatures get high enough to melt marine deposits (on the continental slopes) oceanic sediment at water depths greater than 300 m where the bottom water temperature is around 2 °C. Methane hydrate or methane ice, is a form of water ice that contains a large amount of methane within its crystal structure (a clathrate hydrate). Methane hydrates can melt, releasing methane gas (a very potent greenhouse gas) if the sea temperatures rise high enough.
http://en.wikipedia.org/wiki/Methane_clathrate

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Some people think that the Paleocene-Eocene Thermal Maximum (PETM) climate event could be a useful analogue for the present human induced climate change – particularly because the amount of CO2 released into the atmosphere is of the same order of magnitude as the total of human-caused releases. The PETM injection was probably 1500 Gt carbon over 500-20,000 years)

http://www.giss.nasa.gov/research/briefs/schmidt_02/   (Written in 2003)
About 55 million years ago an event known as the Paleocene-Eocene Thermal Maximum (PETM) occurred. This was an episode of rapid and intense warming (up to 7°C at high latitudes) which lasted less than 100,000 years.
At present, methane has a residence time of about 10 years before it is oxidized to carbon dioxide. However, the chemistry of this process is highly non-linear, and as emissions increase, the capacity of the atmosphere to deal with the excess methane decreases and the residence time lengthens. This can lead to quite large increases in the methane concentration. This matters because molecule for molecule, methane is a more powerful greenhouse gas than carbon dioxide (inserted by PS: 23 times). The climate consequences depend very strongly on exactly how long the extra methane hangs around.
Full paper: http://pubs.giss.nasa.gov/docs/2003/2003_SchmidtShindell.pdf

http://en.wikipedia.org/wiki/Paleocene-Eocene_Thermal_Maximum

www.geosc.psu.edu/people/faculty/personalpages/tbralower/Bowenetal2006.pdf
(Written in 2006)

http://environment.newscientist.com/channel/earth/mg18625044.700-ancient-glimpse-of-seas-bleak-future.html
http://physorg.com/news4491.html

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And now to the unknown unknows! The Natural Step program has developed a very good approach to this. The line of thinking runs as follows:

- If humans systematically change environmental conditions in any direction then this will eventually take the environment out of it normal range of conditions and then things will change – perhaps in quite surprising ways. But what we know for sure is that once the gets out of it's normal range (whatever that is – and we may not know for sure) then the most unlikely result is that things will keep going without any major changes. And it is most likely that the changes will not be largely beneficial in the medium term because the environment will have to evolve a new optimum and this will take time.
- The conclusion that the Natural Step draws out of this line of thinking is that we should not systematically perturb the environment in any one direction for a long period of time.

We know, based on very rich and reliable data that for at least 1 million years the atmospheric CO2 has varied between 200 ppm and 300 part per million (ppm). You can see 400,000 years of this history in this slide. You can also see (the green dot) that actual CO2 levels are now well out side the 'normal' range – 383 ppm. And if you take into account the warming effect of the other greenhouse gases then the CO2 equivalent level that would produce the same climate effect is 430 ppm according to the IPCC (draft 4th assessment report) and the Stern Review, or 490 according to Prof Danny Harvey at the University of Totonto.

So there's no doubt that we should expect some quite unusual behaviours of the environment, much of it damaging.

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Having set the scene, showing something of what might go wrong if we fail to take appropriate and timely action, we can now look at what the best approach might be for setting response targets.

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What kind of dynamic are we facing?

One way to bring all the information together that has been discussed so far in a simple mental model is to imagine the Earth starting off with Nature's economy – that is – all the natural habitats, marine and terrestrial. Then beginning perhaps 8 thousand years ago humans started removing parts of nature's Economy (the natural environment) to make room for their own economic sectors – the first being primary production. Then a bit over 250 years ago another sector of the human economy started to expand dramatically and that was the secondary sector – manufacturing. This was the start of the industrial revolution and from, then on, and increasingly so, the human sectors of the economy started to grow.

So now we have a clear picture of Nature's economy being increasingly rapidly removed and the human economy increasingly rapidly expanding.

But the human economy not only expands spatially, it also tends to degrade the health or quality of the Natural economy.

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The upshot of these three changes:
- the exponential decline in Nature's economy
- the exponential increase in the human economy
- the overwhelmingly negative impact of the growing human economy on the quality or health of Nature's economy

is that the ratio of indirect costs of producing products in the human economy (externalities) versus the direct costs is a hyper-exponential function.

The ratio goes from being less than one (direct costs are perceived by people to exceed the indirect costs) to all of a sudden switching massively so that, seemingly, in the blink of an eye the indirect or external costs are the overwhelmingly important cost.

It is now clear that we very recently reached this inflection point and in fact have probably just gone past it – which is why we are now deluged with more and more information suggesting that we are in deep trouble over the environment.

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What this 'flip' model on the previous slide does so well is that it brings together concern for not only the type of changes we need to make so that the human economic sectors do not overwhelm Nature's economy but it also links the issue of scale and speed together. Having two exponential functions – one a decline and one an increase – interacting, means that it is inevitable that at some point the human economic sectors will dwarf the natural economic sector (a scale issue), but also this change in scale is happening ever faster so suddenly we are faced with an extraordinarily rapid rise in the risk of collapse of both Nature's economy and the human economic sectors.

This very sudden change in scale and speed relations also has very important social or political implications, and I will return to this question shortly.

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Article 2 of the United Nations Framework Convention on Climate Change states its ultimate objective as: "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference (DAI) with the climate system."

Dangerous anthropogenic interference in the climate is warming that creates an unacceptable risk (ie. *possibility*) of unacceptable impacts.

Link for text of the United Nations Framework Convention on Climate Change:
http://unfccc.int/essential_background/convention/background/items/1349.php

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Before we select a greenhouse gas reduction target we need to be very clear about how we want to handle risk. We need to go back to our starting point. In slide 7, I argued that we needed to anchor our targets on a commitment to actually achieving sustainability, that is, the ability to sustain some quite specific things: people and other species (from a compassionate or ethical or moral point of view) and life support systems/ecosystem and geosystem services (from a practical point of view because we and other species depend on them).

To sustain something means not to lose it before you intend to. And it's pretty clear that we don't want to put a use-by date on people, other species or life support systems/ecosystem and geosystem services. We want to sustain people for the maximum of their natural life, and species and life support systems/ecosystem and geosystem services we want to maintain in perpetuity. So what does that mean for the level of risk we would want to take? Logically, at a very basic level, that means taking no risk!

But we know that even though we don't want people to die from accidents we don't necessarily create a no-risk world. How much risk do we accept consciously and unconsciously for things that really matter?

Regulatory bodies like the US EPA & the Nuclear Regulatory Commission set a standard that facilities must not have a risk of fatalities that exceeds 1-in-one million.(1)

But is that realised in practice? In the case of aviation, the level of safety actually achieved in the US has been, since 1997, one fatality in every 2000,000,000 miles flown.(2)

So in all these cases we accept risk to a degree – but only to a very small degree. We seem to accept much less than a 1% chance.

Let's use this "less than 1% chance risk level for what follows.

(1) "Dangerous anthropogenic interference, dangerous climate change, and harmful climatic change: non-trivial distinctions with significant policy implications", Climatic Change (in press) http://www.geog.utoronto.ca/info/facweb/Harvey/Harvey/aspapers/HARVEY_DangerousAnthropogenicInterference.pdf

(2) US aircraft safety: "since 1997 the number of fatal air accidents has been no more than 1 for every 2,000,000,000 miles flown" – source - http://en.wikipedia.org/wiki/Air_safety

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This diagram is a very good graphic for understanding the relationship between:

- atmospheric levels of CO2 and other greenhouse gases
- probabilities that certain levels of warming will occur, and

- the setting of emissions limits.

In 1997 Azar & Rodhe, using the best available information at the time, put together the model described in this slide. The Intergovernmental Panel on Climate Change (IPCC) had generated a series of climate stabilisation scenarios. These stabilisation trajectories are plotted out on the left of the graph. You can see how atmospheric CO2 levels rose, using historical date up till about 1990, then 6 alternative stabilisation scenarios are generated using computer modelling. The scenarios show atmospheric levels of CO2 that grow, at least for a while, and then end up at 350 ppm, 450 ppm, 550 ppm, 650 ppm, 750 ppm and 1000 ppm of CO2 in the air. The 350 ppm stabilisation level is the closest to the pre-industrial maximum, 280 ppm, but nevertheless exceeds it by 25% and is even 18% over the highest CO2 level experienced in the last million years or more.

But, despite the 350 ppm target being significantly outside the very long run normal band, to stabilise at this level it is necessary to:

- stop the growth of CO2 emissions
- drive emissions down to.... zero, and
- take excess CO2 out of the air!

The next part of the graph, on the right hand side, shows the spread of possible temperatures that the different stabilisation targets might give rise to. The reason why there is not one single temperature for each atmospheric stabilisation target is because (a) our knowledge and modelling capability cannot be that precise, and (b) because natural systems are chaotic in the technical sense that if you could follow the ‘real’ earth into the future many times from the same starting point, the end points would not be identical but would create a probability distribution of possible futures.

You can see from the graph that in 1997 is was believed that stabilisation the atmospheric level of CO2 at 1000 ppm could produce a temperature somewhere between 3ºC-9ºC. The temperature distribution starts with the temperature which is thought to have a 95% chance of being exceeded and closes with the temperature that is thought to have only a 5% chance of being exceeded. In between is a temperature marked with a dot that is thought to have a 50-50 chance of being exceeded. Using this structure, the 350 ppm stabilisation scenario was thought to have a possible temperature range of ~1.8ºC to 2.7ºC, with there being about a 50% chance of having 1.5ºC of warming.

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Before we try to generate our greenhouse gas reduction target, we need to establish one more guiding principle.

We need a simple model that can help us create appropriate dynamics for the Earth to remain within a sustaining safe zone or to return to this zone if we have strayed beyond it.

Anyone who cares for living organisms (parents, farmers, scientists, indeed everyone of us in relation to caring for ourselves!) will be familiar with some aspect of the idea of homeostasis. Let’s take the example of heat regulation. Almost all adult humans have a normal body temperature of 37ºC and when we are sick the temperature usually rises but most often not above 40ºC. Considering that most of the time, for everyone, the surrounding temperature is outside the 37ºC-40ºC range this is remarkable. But our bodies have a suite of mechanism to keep us in the safe range. If we are hot we sweat to cool, and if cold we shiver and rub ourselves to warm. And the body triggers us (via discomfort) to take more complex actions to control our temperature if the body's internal mechanism are struggling eg. move into or out of the shade/sun, put on or take off clothes, use heaters or coolers, etc.

All living things deploy both prevention and restoration strategies to maintain and return to the safe zone for survival and wellbeing.

The Natural Step organisation has developed some simple but powerful rules for preventing a move away from a sustaining state. But as yet we don't have similarly powerful rules-of-thumb guide restoration of a sustaining state. But with a little thought we can do a reasonable job of applying the homeostatic model to environmental and social sustainability questions.

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We now have a compilation of more recently estimated probabilities in the report of the Stern Review, 2006 (Box 8.1, p. 195). This data has been re-laid out here to make it easier to see the relationship between atmospheric concentrations of CO2 equivalent and the probabilities of triggering a range of different temperatures. I have also added estimates of (a) expected species losses; (b) the likelihood of runaway warming; (c) a qualitative characterisation of the total impact associated with different temperature rises.

This is probably the most important slide in this whole presentation. I am going to use this model to home in on a preferred greenhouse gas reduction target. So here goes! The environmental, social and economic impact of global warming is largely a function of the temperature rise. There are also some direct chemical effects that are a function of the CO2 concentration (eg. ocean acidification, peat carbon mobilisation).

The first step is to reiterate that the target that we will generate is based on: (a) a commitment to actually achieving sustainability; (b) a commitment to sustain both people and other species in perpetuity for compassionate and practical reasons; (c) a risk aversion standard of "less than 1% chance of 'crashing' the planet" (ie. triggering runaway warming; and (d) a very strong preference to substantially reduce the damage for the most vulnerable and least able to cope – the poor and other species.

Now let's test how well we can read the chart. The UK Government has a policy commitment of keeping the total concentration of CO2 equivalent (CO2e) in the air to 550 ppm. The UK Government and the European Union also have a policy commitment to avoid 2ºC warming. So we will now go to the row in the middle of the chart that relates to an atmospheric greenhouse gas concentration of 550 ppm CO2e. We can see that there is a 100% chance of *exceeding* a 1.5ºC warming. In the 2ºC column there are four probabilities offered which estimate the risk of *exceeding* 2ºC. Different models produce different estimates of risk and the Stern Review presented four estimates that spanned the range of models from those that generated high estimates of risk to those that generate low estimates. The Stern Review favoured the probabilities second from the left which were compiled by the Hadley Centre. For convenience I will concentrate on this subset of the probabilities.

We can now see that Hadley Centre estimates that with 550 ppm of CO2e in the air there is a 99% risk of exceeding 2ºC, a 69% risk of exceeding 3ºC, a 24% risk of exceeding 42ºC, and a 7% risk of exceeding 5ºC. Since runaway heating is, according to James Hansen of the NASA Goddard Space Centre, likely to be triggered by an initial warming of between 3ºC and 4ºC, having 550 ppm of CO2e clearly is unacceptable. So what is an acceptable level of atmospheric greenhouse gases? Let's work through each atmospheric CO2e level until we find one that has less than 1% chance of triggering runaway heating.

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It turns out that ***all*** of the CO2e atmospheric stabilisation levels for which we have data from the Stern Review (ie. 400 ppm – 550 ppm) have an unacceptable risk of triggering runaway heating (!) and all of them also have an unacceptable risk of exceeding 2ºC warming and the biodiversity-preferred 1.5ºC warming. So what about CO2e atmospheric stabilisation levels below 400 ppm CO2e? If we are to care effectively for biodiversity (keep the warming *under* 1.5ºC) we it looks as if we would need under 400 ppm CO2e – possibly quite a bit under.

But there's a catch! According to the Stern Review and the IPCC draft 4th Assessment report the level of CO2e in the air right now is 430 ppm. And Prof. Danny Harvey from Toronto University believes that the correct figure is 490 ppm (pers. comm.) **So we have already passed what looks like a safe level of greenhouse gases in the air – by a considerable margin – we are at 430-490 ppm CO2e instead of well *below* 400 ppm CO2e.**

If we were to target a warming of less than 1.5ºC we may have to take greenhouse gas concentrations ***under*** the long run desirable stabilisation gas concentration to offset the positive feedbacks for warming that have by now been triggered in the global environment.

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Read slide contents....

So how do we handle the whole challenge? How should we frame our reduction targets?

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Turning back to an earlier graph.......Slide 30

We clearly face a challenge bigger than we ever imagined. The hyper-exponential 'flip' diagram makes it easier to understand what is going on. The scientific data is showing us that indeed the side effects of the human system are going into overdrive – simultaneously affecting both the scale and speed of the problem.

There is no longer any room for slow small scale incremental responses – there is simply no time left.

So we have to get as many people who can handle it emotionally and intellectually up to speed on the issue, and engage them in putting solutions in place that will actually solve the problem.

At this moment in time the number of people who are deeply aware (intellectually and emotionally) of the scale and urgency of the problem is very, very small. We need to get the message out quickly to boost those numbers.

But a lot of people will (initially at least) no want to ‘hear’ how things really are, because the situation is too challenging. Most people’s understanding has evolved personally and culturally during the long period when the indirect costs of development were not so great that they could not be ignored. The environmental reality that we are now rocketing into now does not feel real to most people because they and their social networks do not have an experience base that can make sense of it.

So should we water down the message and the targets and the actions so as to not frighten or overwhelm or anger people? I don’t think so. Because people can’t work on the climate issue realistically if they don’t really know its scale and urgency. and they can’t solve it unless they work on the problems that we really have.

So how do we deal with this dilemma? I think the only way through (that I can think of right now) is to have a dual approach. We need a program to reach and engage people who can cope with an unfiltered version of reality. Then these people need to develop programs and projects in partnership with people who are not yet able to cope with the full emotional and intellectual impact of the situation. These programs and projects have to be designed to makes sense in terms of a very rapid physical and social transformation to achieve sustainability and they also have to be engaging for people who are still working through to a full understanding of our situation.

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Applying this insight to the framing and use of targets.......

It is helpful to distinguish between strategic and tactical targets. Strategic targets are those that really need to be achieved if ones high order goals are to be achieved eg. sustainability. Tactical goals might be used to move tings along in the short term but they should never be presented as the ‘real’ goal. It is really important that the strategic goals guide both education and innovation and solutions design. If the real goals are not use then it is extraordinarily unlikely that they will be achieved.

Great care needs to be taken with even interim (ie. tactical) targets. Are they applying to the characteristics of the whole system or just to any new developments? If you had a project to covert all letter boxes from red to blue over 12 months you might set a 50% achievement target for 6 months. But does that mean that people should start painting the letter boxes purple (50% red, 50% blue) or do you want people to paint ***all*** new letter boxes blue and to have completed half the boxes in 6 months? If interim targets are describing the whole-system they need to be accompanied by different targets for the performance of all new increments to the system.

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People are often concerned to take account of feasibility in setting goals. If it doesn't really matter if the goal is achieved or not that is OK. But if achieving the goal matters a lot then issues like cost and ***current*** feasibility should no change the goal. Instead the action strategy should start with a commitment to achieve the goal despite any problems with cost or feasibility and then the action plan should include actions to cut costs or raise revenue and actions to innovate until a feasible solution emerges.

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It is also important to take account of the likelihood that actions taken to achieve a goal may fall short of the hope for outcomes. One way to handle this is to get people to go for an even tougher goal in the hope that when they partially fail that what they do achieve adds up to the original 'real' goal.

If the real goal is very demanding (ie. there is not much room to to set up a tougher aspirational goal) then the best way to ensure that the goal is achieved is to build in excess capacity (ie. you might think that 3 measures are sufficient to achieve the goal if they all work, but instead you might initiate 6 projects hoping that shortfalls in some will be offset by achievements in the others).

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Often people feel that they cannot establish a goal unless they know exactly how it is to be accomplished. But if the goal is important then this approach is not appropriate.

Instead it is better to use the stretch goal method. First you work out how far you can go with current methods. Then you work out the gap between the goal and current performance capability. If the goal has to be achieved with one integrated response package (eg. getting to the moon) then you set up an innovation program and keep going on this until a solution that can close the gap emerges. Or if the goal can be achieved through the sum of separate projects then you can simultaneously implement the current methods to get at least part of the way to the desired goal and you also run an innovation program to work out what can be done to close the gap.

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So at last we come to the point of setting an appropriate, realistic and practical greenhouse gas reduction target.

We are committed to sustaining all people and other species (and the supporting life support systems and ecosystem and geosystem services) and to actually achieving this result. This goal is considered to be so important that we will take account of all the practical limits, barriers and difficulties in our action plans and not in the framing of the goal itself.

So what should we do?

We have found that we already have too much CO2 and other greenhouse gases in the air. This means we must adopt a zero emissions target and we must take CO2 out of the air (it's the most long-lived high volume greenhouse gas) with below 400 ppm CO2e as the stabilisation target.

It appears that we do not know enough about the system dynamics of the world in the range of atmospheric CO2e from the pre-industrial to about 400 ppm CO2e. We especially need some scientific work to be done on best return trajectory to the safe zone given than we have to stop anthropogenic emissions altogether and we have to take CO2 out of the air and need to keep the temperature under a 1.5ºC warming.

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The momentum in the economy to keep emitting and expand the emissions of greenhouse gases is so strong that we know we will have to take extraordinary action to change the physical behaviour of the economic system. We should plan to make the transition to zero emissions within 10 years and we also, within the Turn-Around Decade, need to set up suitable CO2 sequestration systems and direct cooling systems.

The fastest transformation of an economy from one type to another is South Korea going from a rural economy to a world class manufacturing economy in 20 years. We need to move faster than that!

The US on the other hand totally transformed what it made with its existing industrial structure in the space of 12 months after the attack at Pearl Harbor in 1941.

The sustainability transformation requires both a change in what is produced and also a change in how it is produced. This will take longer than 12 months but hopefully people can work out how to do it in quite a bit less than 20 years.

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Clearly the apparently ambitious targets adopted by the New Mexico, California, UK, SA and Victoria are too slow and are too little.

The UK FOE/George Monbiot target, while being even stronger that the New Mexico target of 85% by 2050, is still not adequate. It's based on the false premise that there is still room for some more greenhouse gases in the air. It's also built on the contraction and convergence model where developed countries make the lion's share of the greenhouse gas emission cuts (because they are responsible for most of the historical emissions) thus allowing the developing world to have the benefit of using the old fossil fuel economy to boost their development for some decades to come. But the developing world is expanding its emissions so fast that they will be responsible for even a large share of all the emissions ever put out if they stay with a carbon-energy based economy for too many decades. In any case, if the world is changing to a a non-carbon economy it is a false economy for developing countries to first build a damaging and obsolete economy and then to have to replace it in not to many years in the future.

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The targets proposed in this presentation are so challenging that it is clear they will not be achieved in either a business-as-usual scenario nor in a modest change scenario. And the difficulty we have had in getting even grossly inadequate targets adopted makes it hard to imagine how anything like what is proposed here could ever be achieved.

It is true that just putting up an environmentally realistic goal will not be enough.

People seem to have evolved to be able to operate in two quite distinct modes: (a) incremental low key normal mode and (b) high performance crisis mode. It is often assumed that it is the actual experience of in-your-face crises that flips people into crisis mode. But I'm not sure that this is anything like the whole story. It is well know that disempowered people can remain suicidally impassive in the face of disasters. Furthermore people who do not understand why a crisis is happening will substitute other apparently plausible explanations and thus they frequently act ineffectively even if they do go into crisis mode.

It seem to me that what is crucial is to have effective education about causation before a crisis hits and to have effective social signalling that society/opinion leaders believe that a crisis coming thus legitimising precautionary action.

We also have two forms of crisis mode – one for military threats and one for civil crises. The military mode makes us look for enemies and we collaborate with allies to destroy the enemy. In the civil mode however we expect cooperation from everyone and we expect to cooperate widely.

One way to tap into this civil crisis mode is to formally declare a state of emergency. This provides the necessary social signaling that the crisis is real and that we are all going to be involved. In this frame of mind we act faster, are less likely to procrastinate, will take on huge 'impossible' (but necessary) tasks and we are more likely to accept some level of short term sacrifice.

If our governments were to declare a state of sustainability emergency we nevertheless need to make sure that the doubly practical targets developed above are driving action on the emergency.

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If you have found the ideas in this presentation persuasive then you might like to take some personal action.

The "zero-minus fast, with cooling" target is not yet well known so we need to get it out there. We also need to make sure that people in all section of society understand it.

One good way to introduce the idea without putting people on the spot is to present it the target and sustainability emergency ideas as the core of a scenario that people and organisations can consider without being put under any obligations.

Once people are familiar with the target and the sustainability emergency concept and the unfolding crisis that were developed to deal with, they are quite likely to take the next step to action relatively easily.

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